

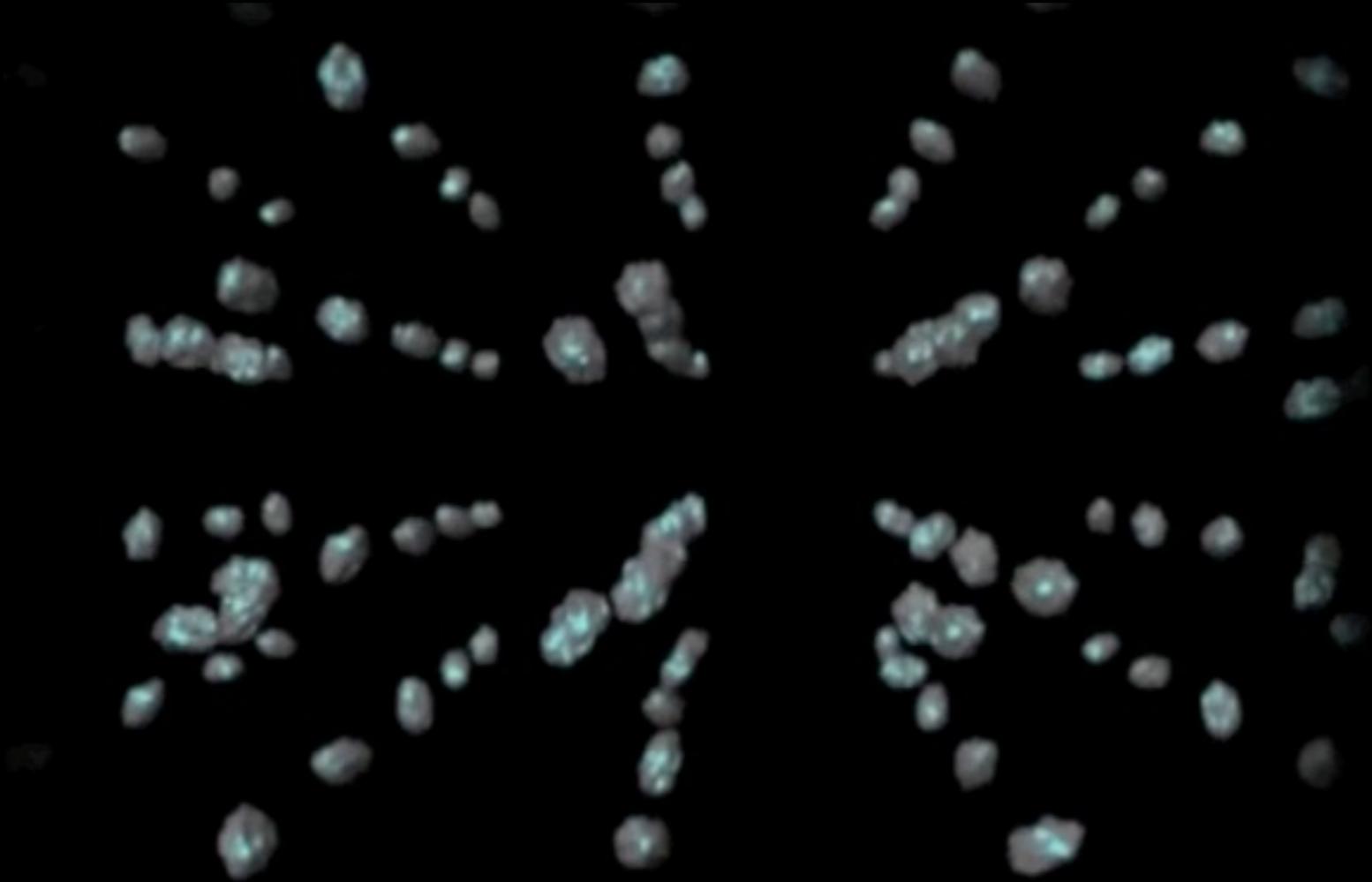
Higgs and Top Quark Physics

Reinhard Schwienhorst
Michigan State University

MSU REU seminar 1/19/2012

The Higgs field

Higgs Field



Fermion in Higgs field

Higgs Field as defenders in football



Higgs at the Tevatron

Results presented in a special seminar
at Fermilab on July 2, 2012

DØ collaboration
CDF collaboration



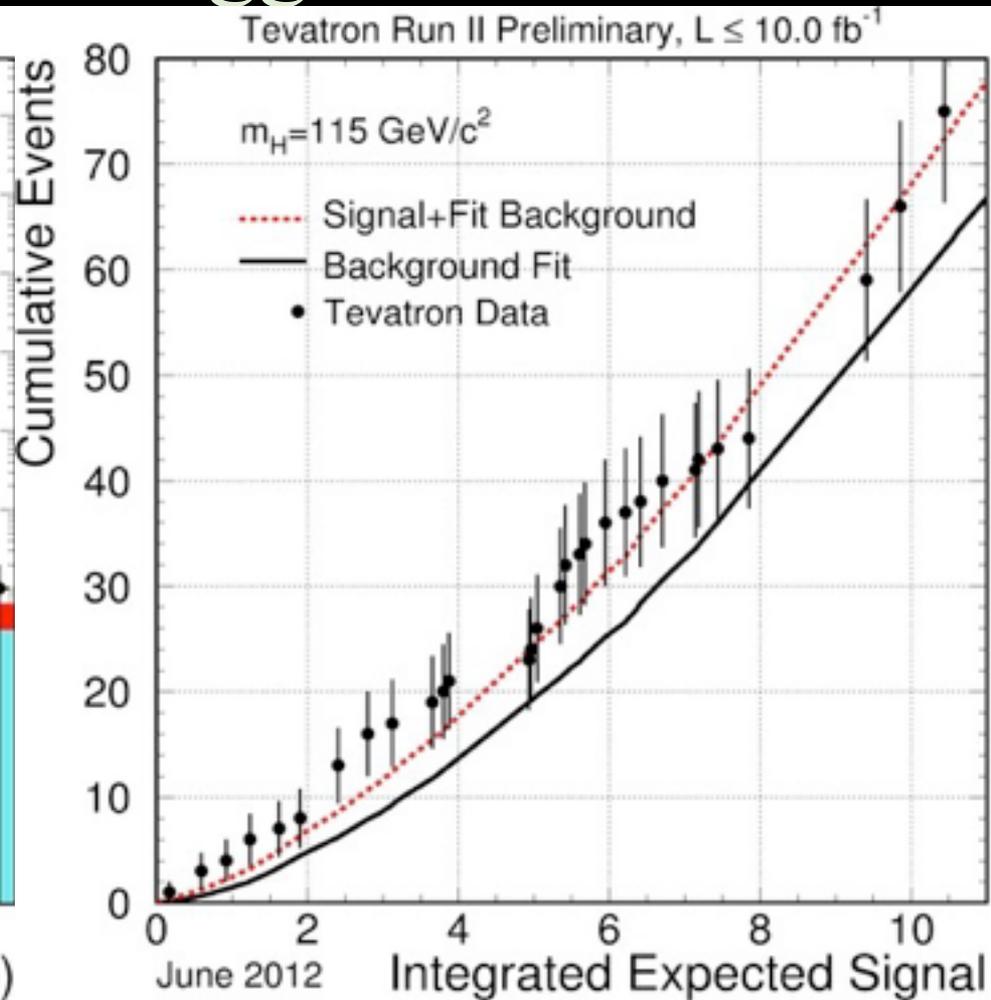
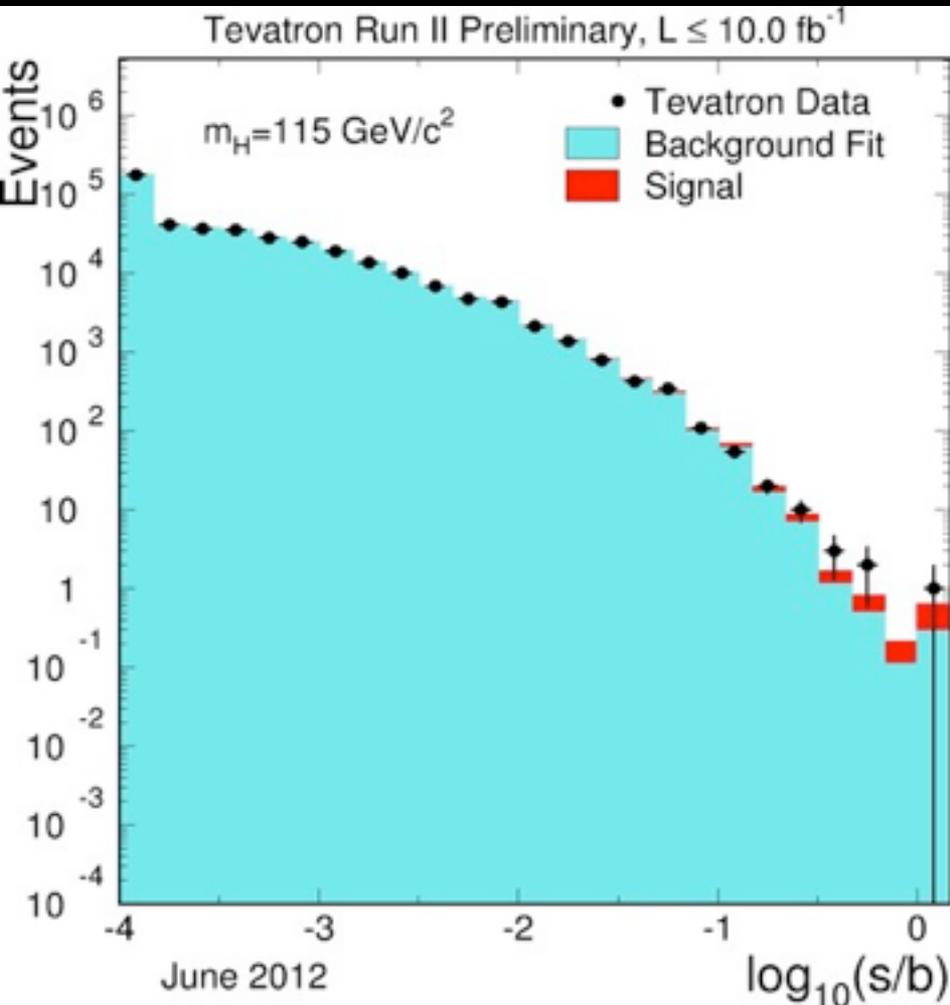
Tevatron proton-antiproton collider at Fermilab



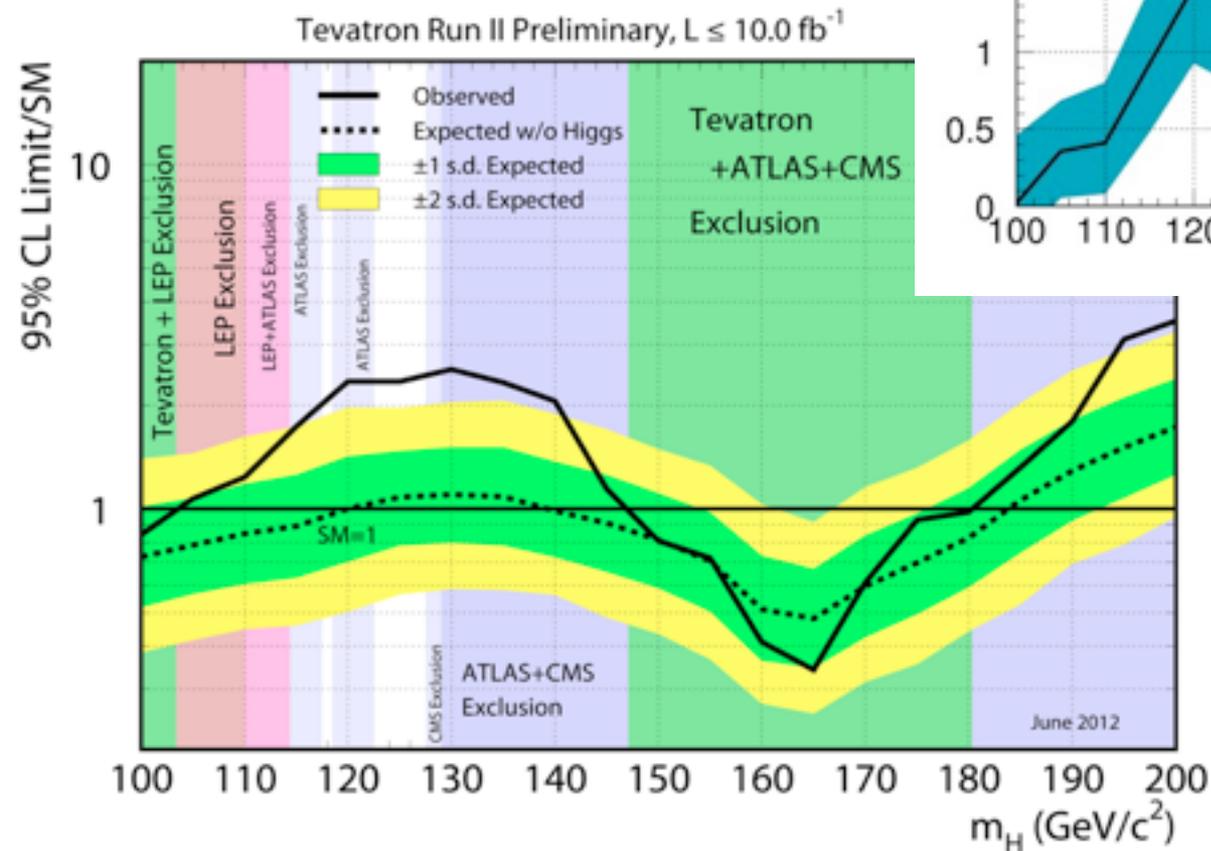
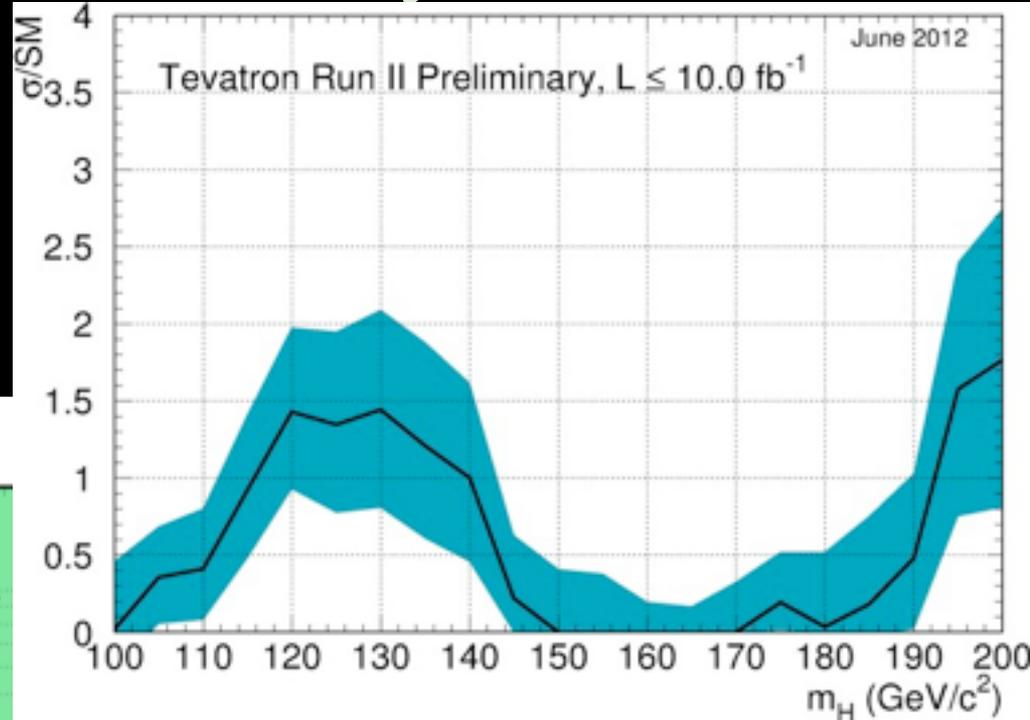
Fermilab seminar

- D0 and CDF experiments at the Tevatron present their most recent results
 - Using all Tevatron Run II data ($\sim 10\text{fb}^{-1}$)
 - Main sensitivity in Higgs \rightarrow bb final state
 - Associated production WH, ZH
 - Ten different final states by each experiment
- Including combination of both experiments

Fermilab Higgs



Fermilab summary



Higgs Discovery

**Results presented in a special seminar
at CERN on July 4, 2012**



**ATLAS collaboration
CMS collaboration**



LHC accelerator as toy slot cars

Large Hadron Collider



CERN seminar

- ATLAS and CMS experiments at the LHC present their most recent results
- Presentations by
 - ATLAS spokesperson Fabiola Gianotti
 - CMS spokesperson Joe Incandela
- All of 2011 data
(5 fb⁻¹ with 7 TeV)
- First 2 months of 2012 data
(5 fb⁻¹ with 8 TeV)

ATLAS spokesperson

Fabiola Gianotti



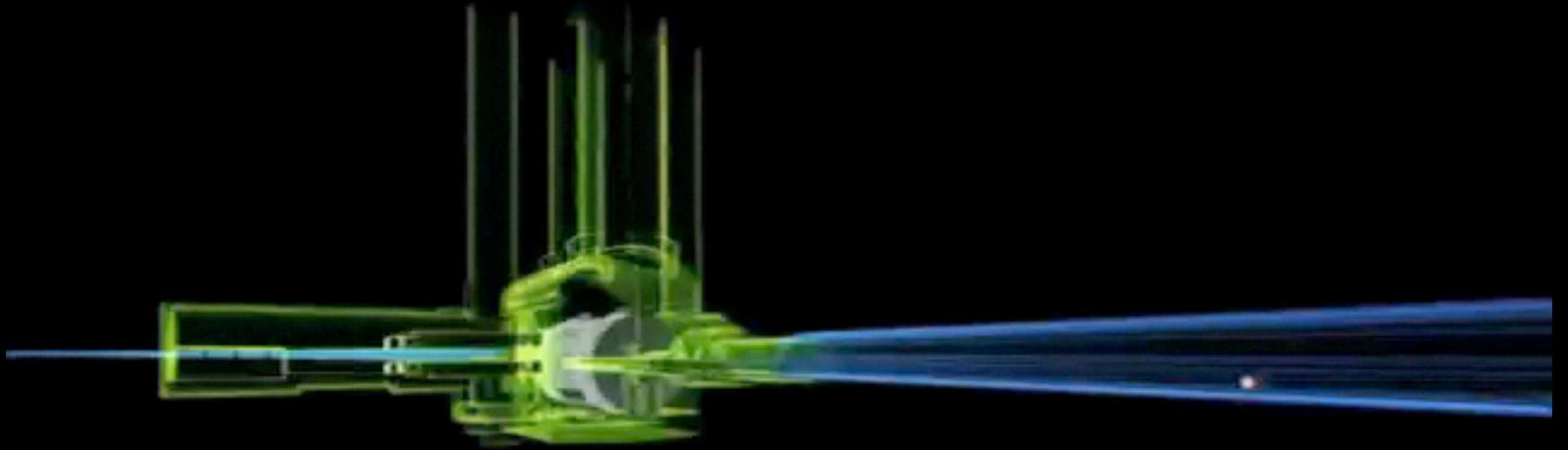
ATLAS results

Higgs events:

2 photons

4 muons

Higgs particle production and decay



 **ATLAS**
EXPERIMENT

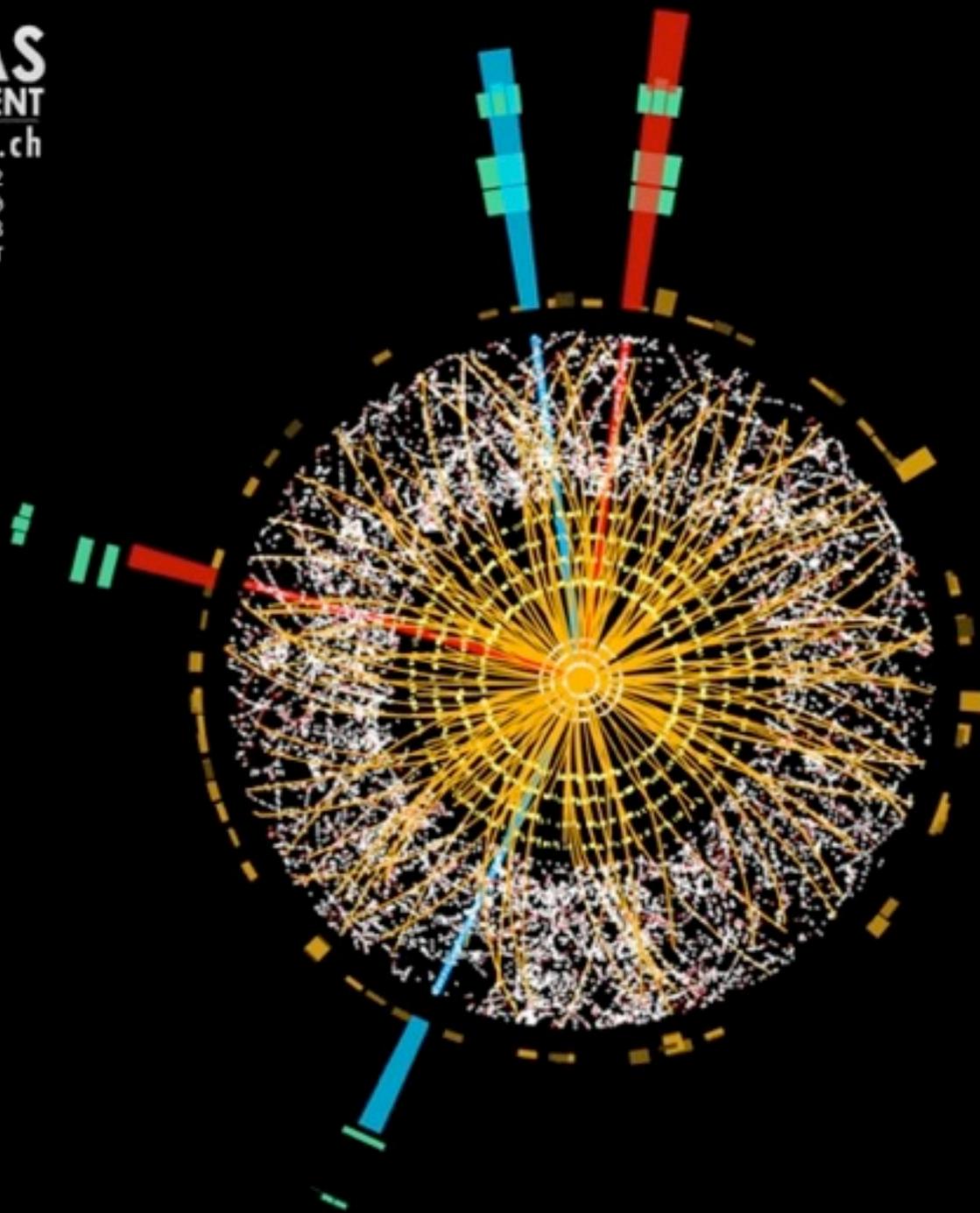
<http://atlas.ch>

Run: 203602

Event: 82614360

Date: 2012-05-18

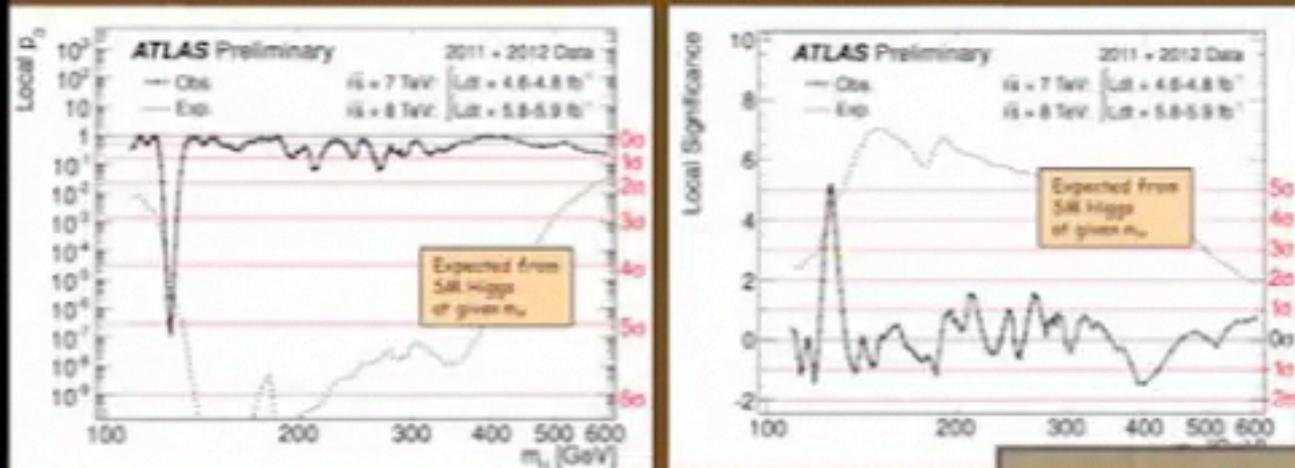
Time: 29:28:11 CEST



ATLAS results

Statistical analysis
summary by
Fabiola Gianotti

Combined results: consistency of the data with the background-only expectation and significance of the excess



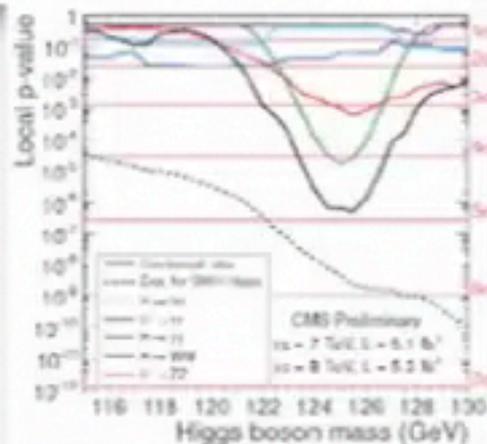
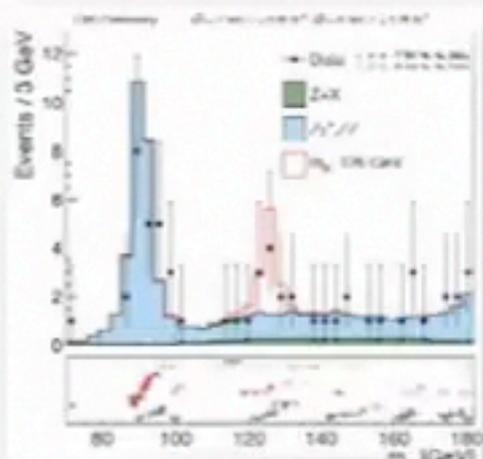
Excellent consistency (better than 2σ) of the data with the b hypothesis over full mass spectrum



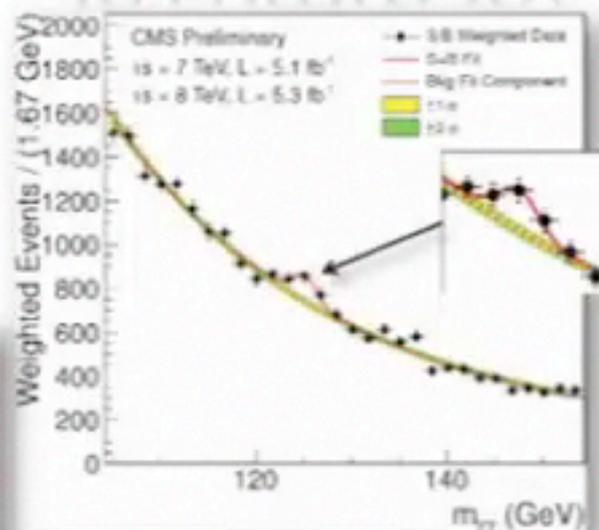
CMS results
presented by

CMS experiment spokesperson

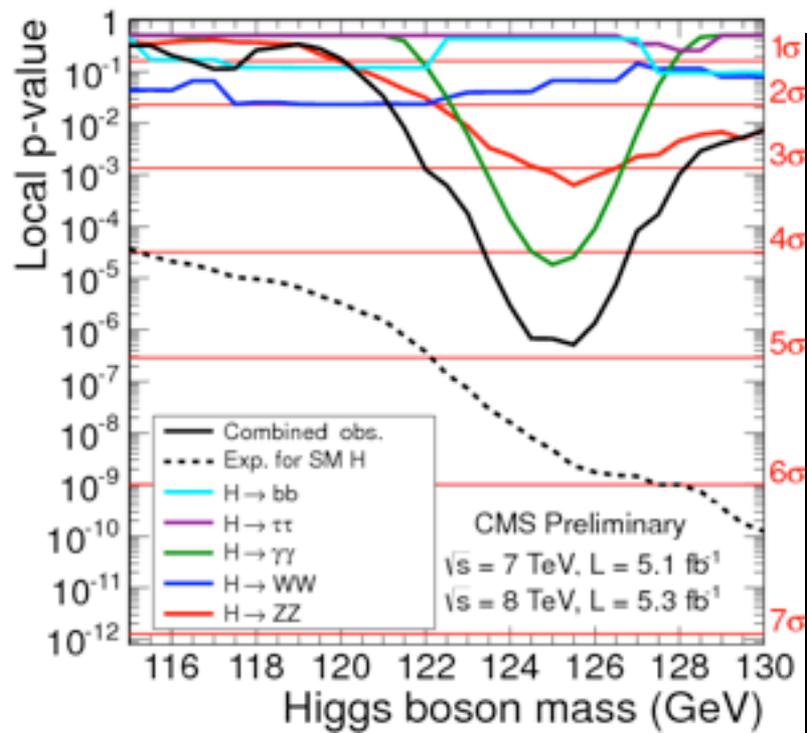
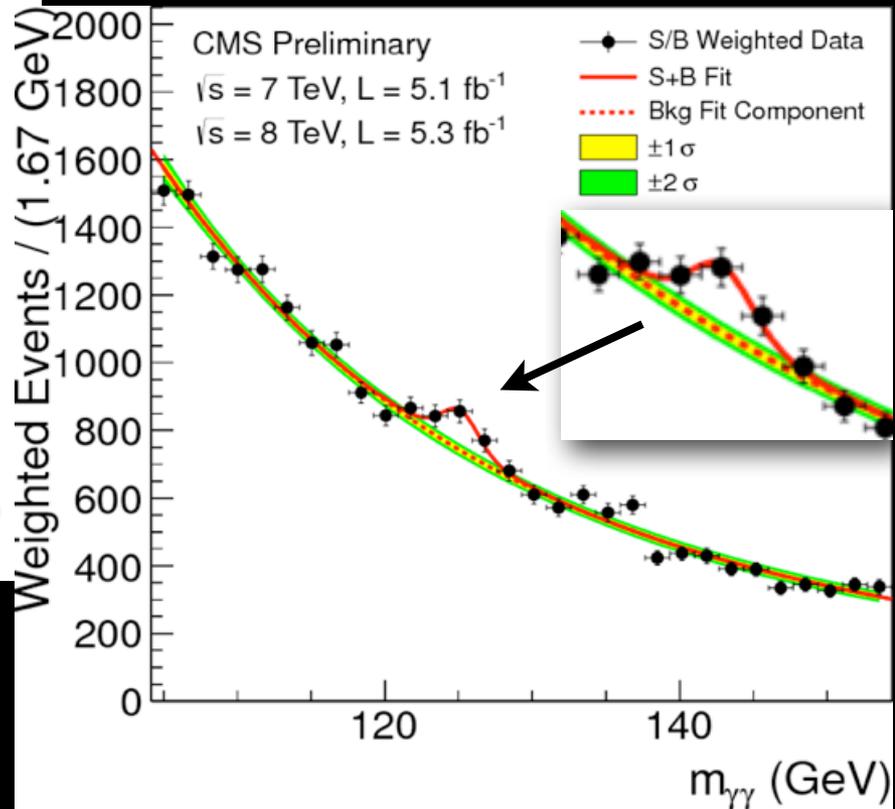
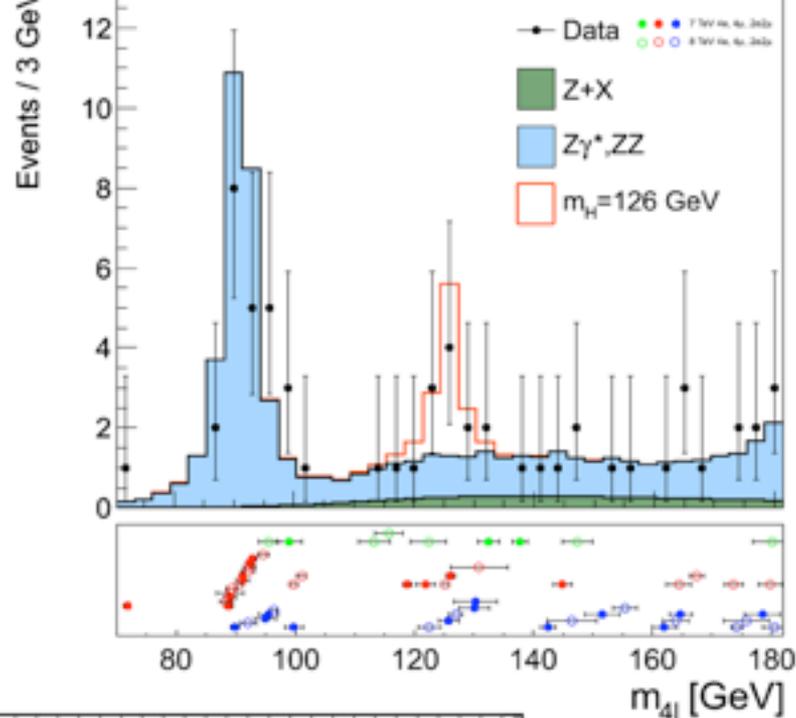
Joe Incandela



In summary

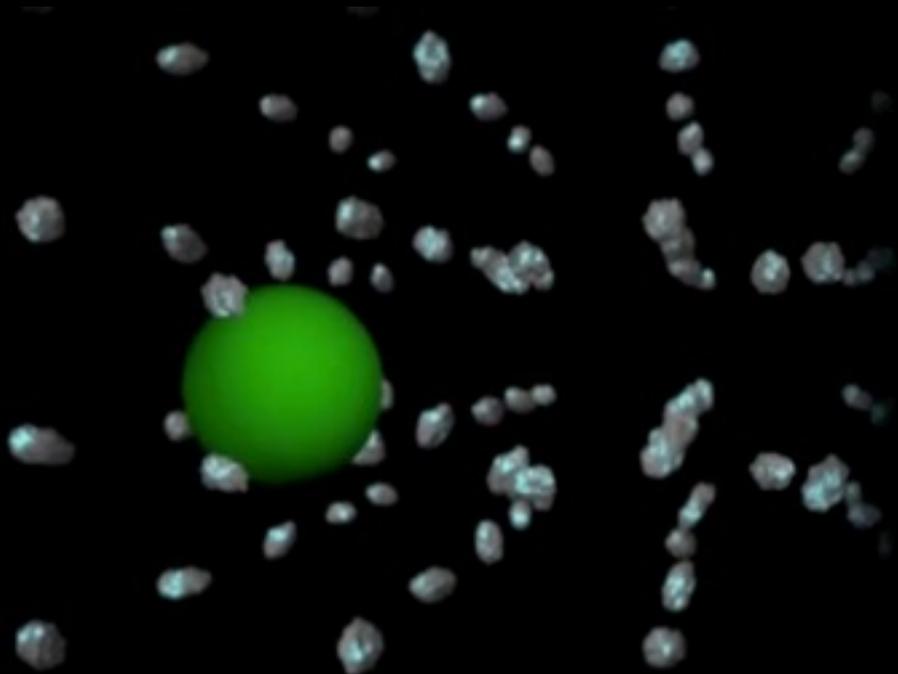


CMS summary

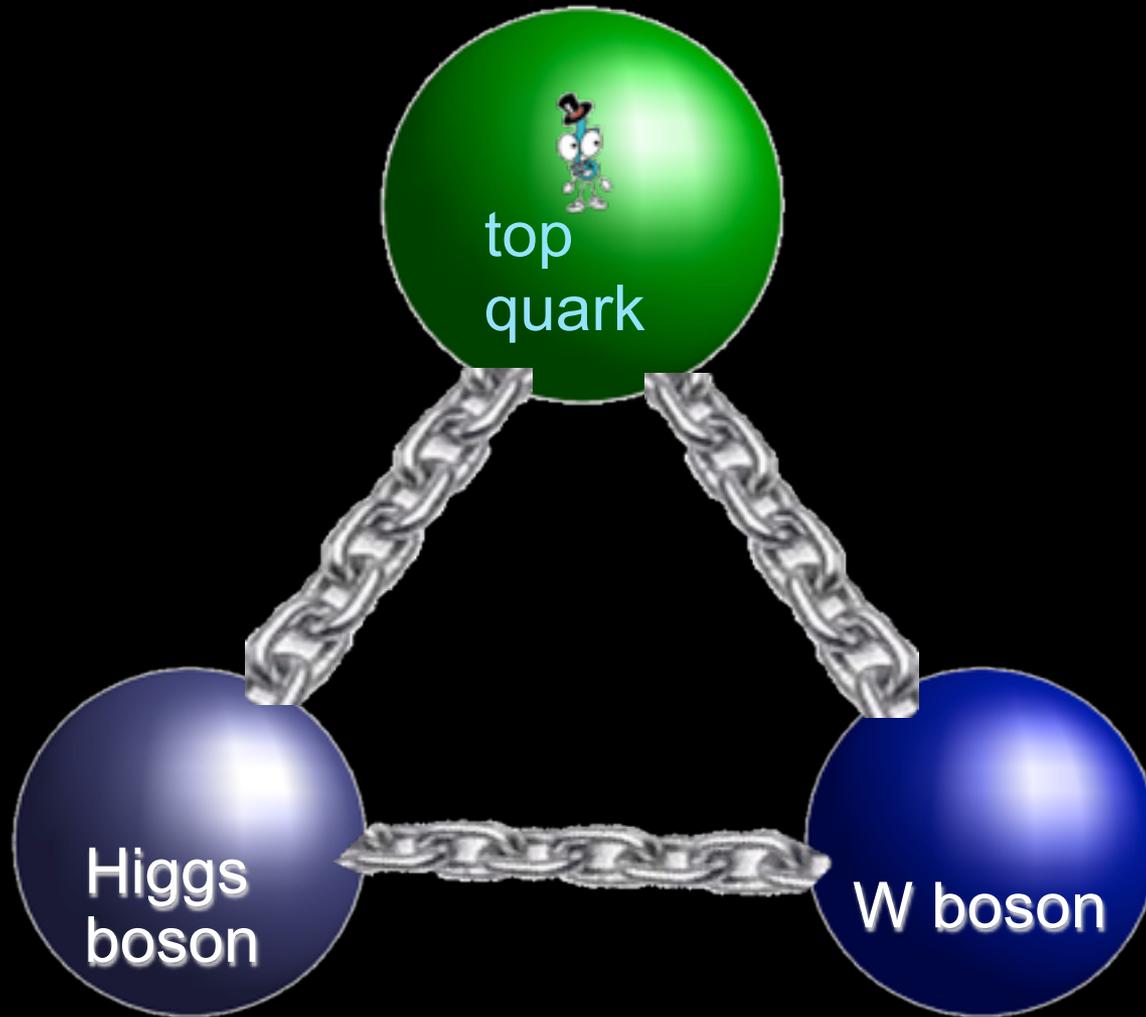


Top Quark

Coupling
strength ~ 1



Key to electroweak symmetry breaking



Central to new physics searches

modified couplings

top-gluon interaction

b'

4th generation quarks

top - W boson interaction

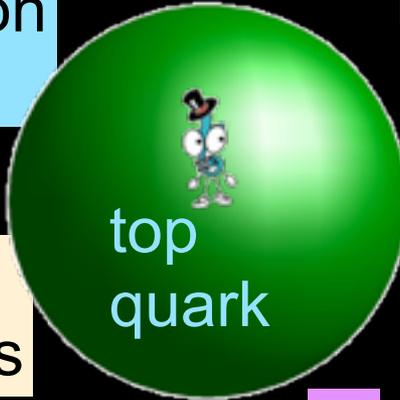
t'

anomalous CKM matrix

other new fermions

new heavy fermions

anomalous Wtb couplings



vector quarks

CP violation

Z'

W'

charged Higgs

Flavor-changing neutral currents

new couplings

new heavy bosons

Supersymmetry

Extra dimensions

Higgs-less models

Other new physics models

Central to new physics searches

modified couplings

top-gluon interaction

b'

4th generation quarks

top - W boson interaction

t'

anomalous CKM matrix



other new fermions

new heavy fermions

anomalous Wtb couplings

vector quarks

CP violation

Flavor neutrinos

gged gs

new couplings



King of the Fermions

new heavy bosons

Supersymmetry

Extra dimensions

Higgs-less models

Other new physics models

Top pair production



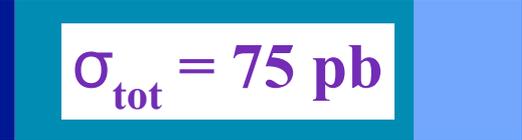
Tevatron:  $\sigma_{\text{tot}} = 7 \text{ pb}$

LHC:
(7 TeV)  $\sigma_{\text{tot}} = 170 \text{ pb}$

Single top production

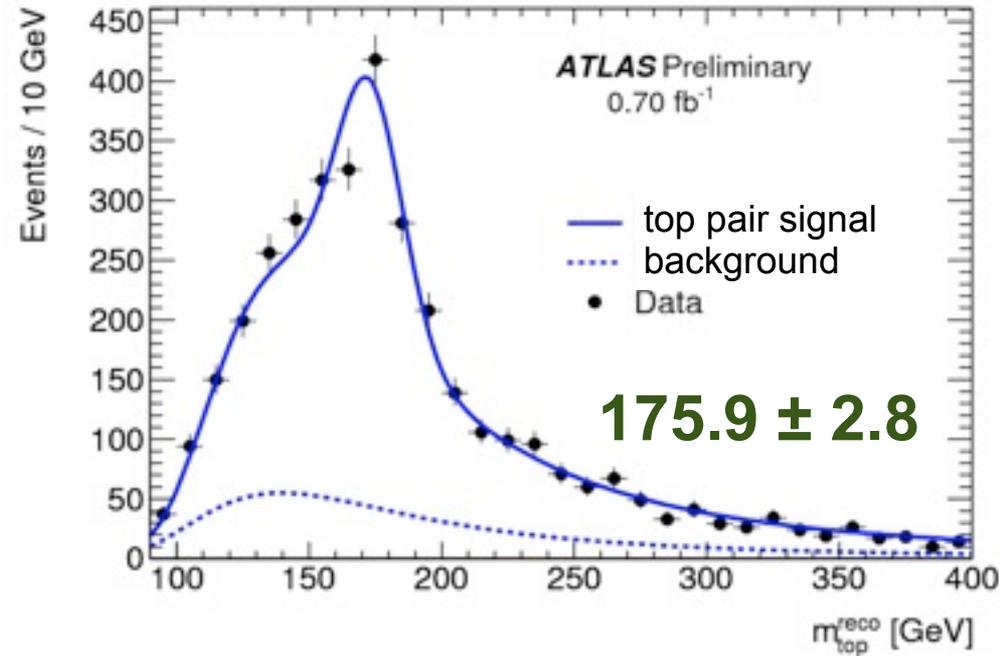
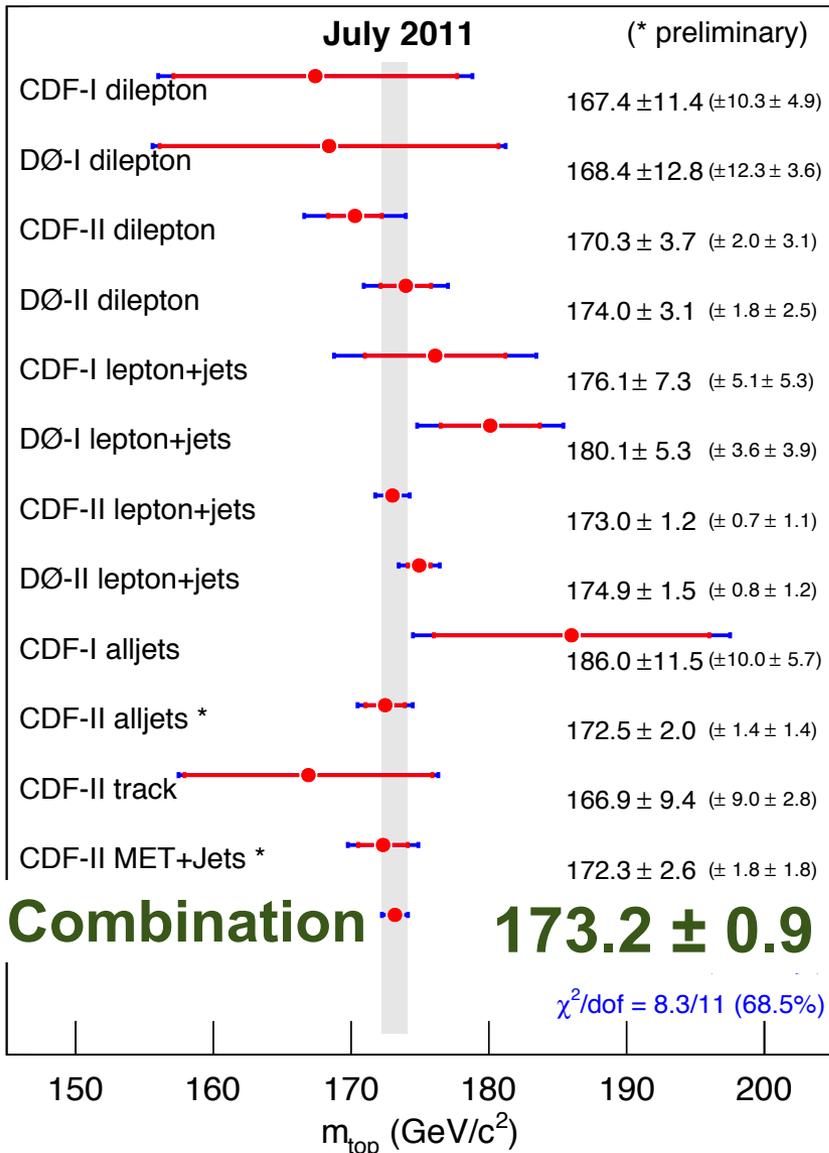


$\sigma_{\text{tot}} = 3 \text{ pb}$ 

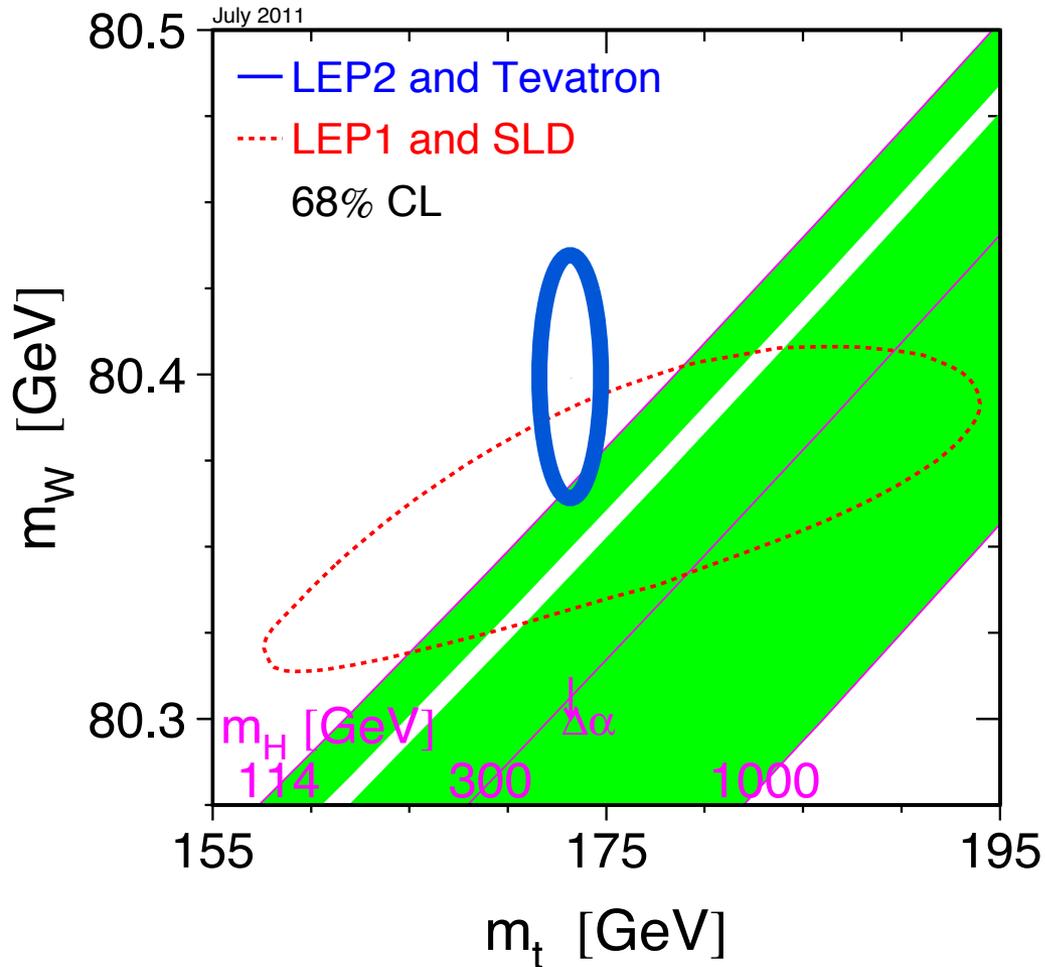
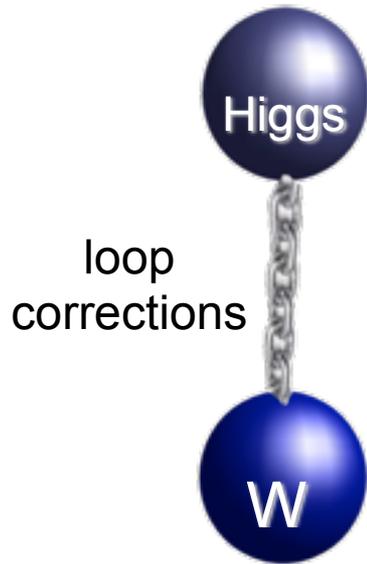
 $\sigma_{\text{tot}} = 75 \text{ pb}$

Top quark mass measurement

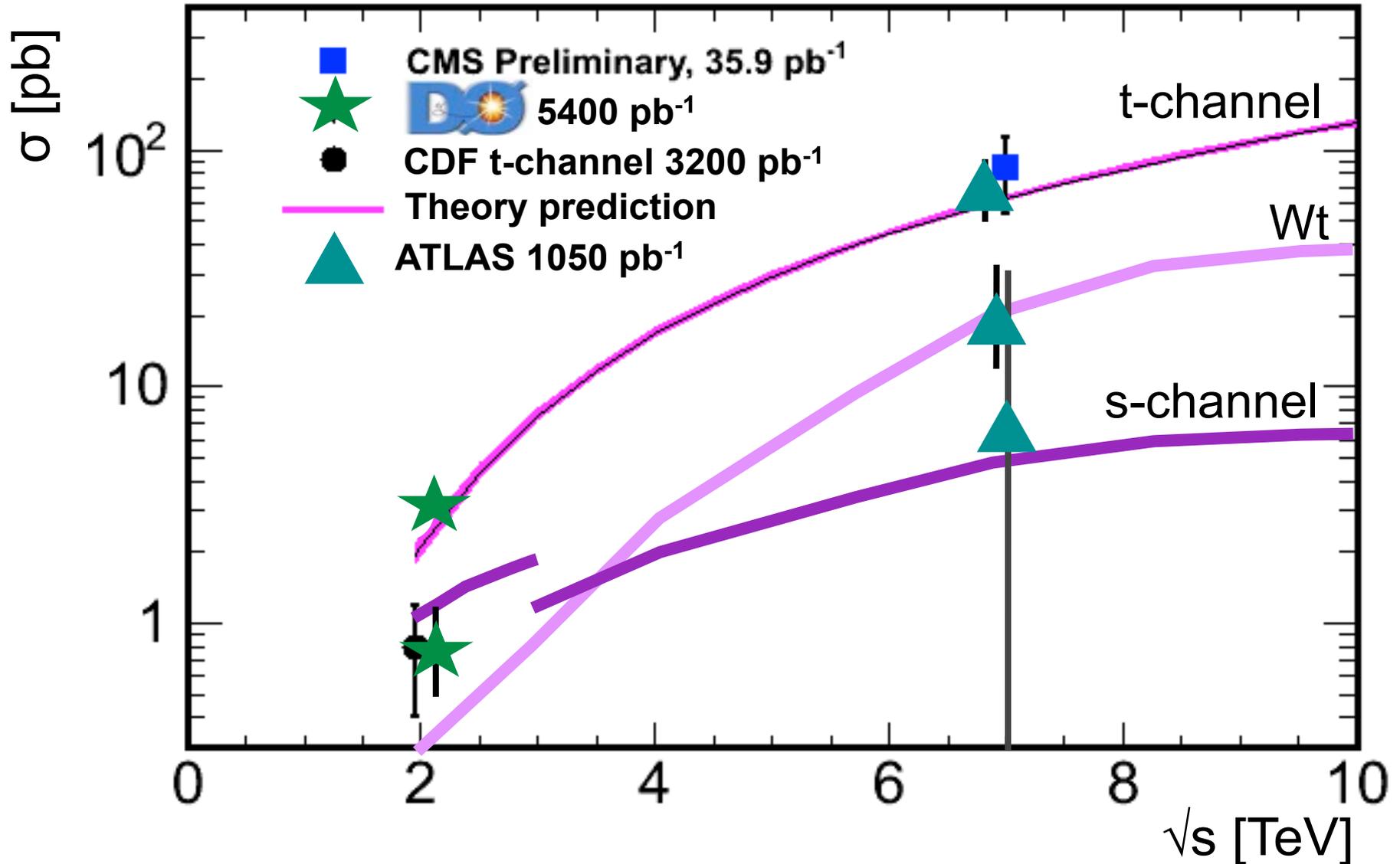
Mass of the Top Quark



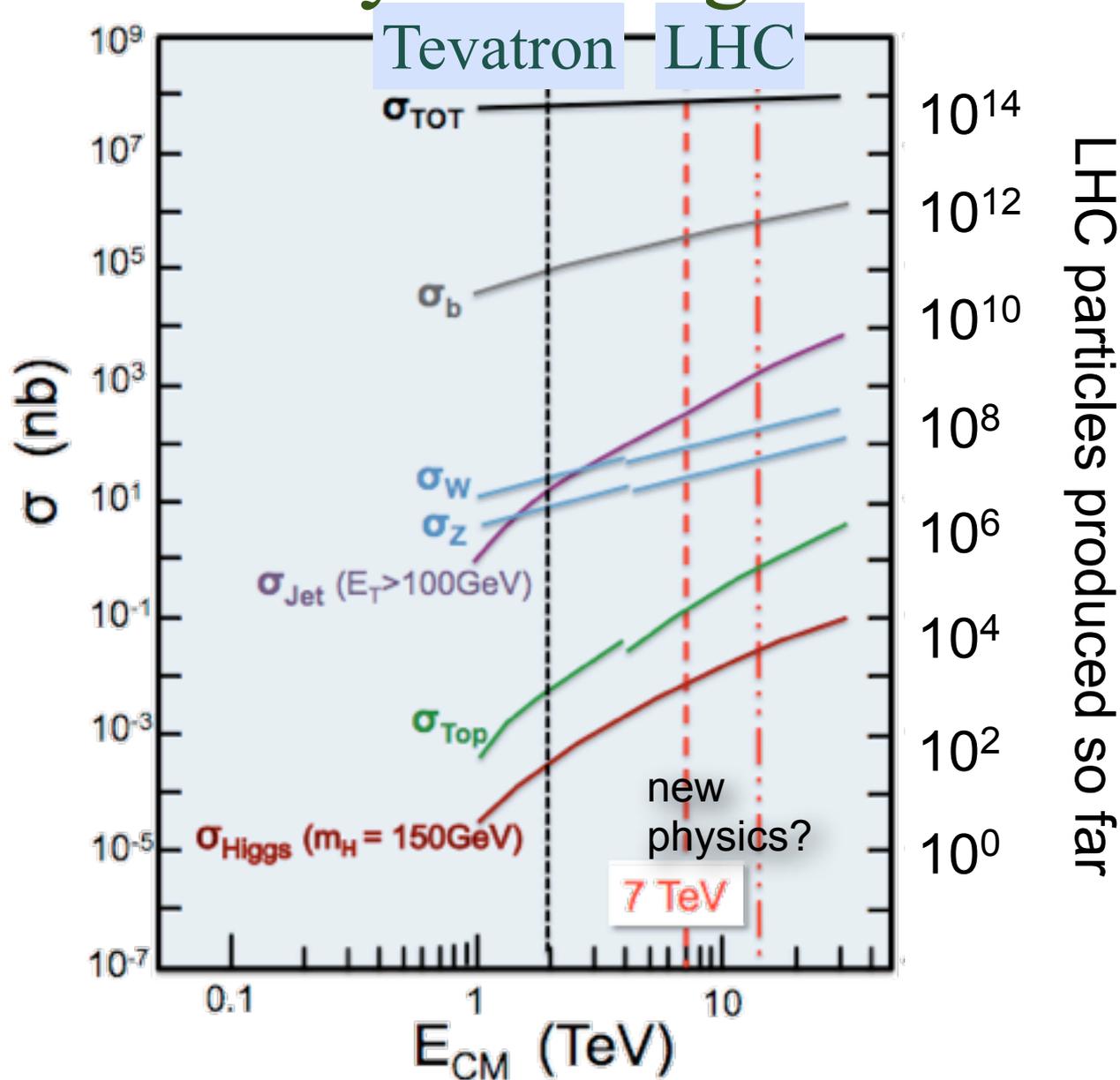
Higgs constraints from top quark mass



Single top SM measurements

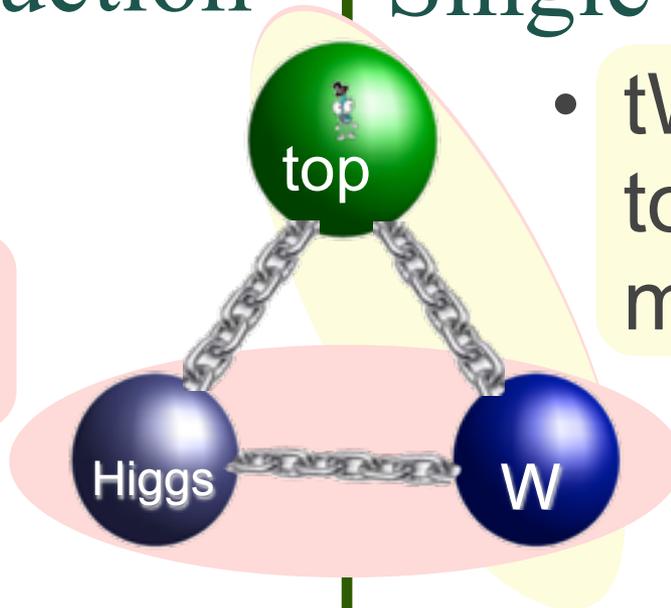


Physics Program



Top pair production

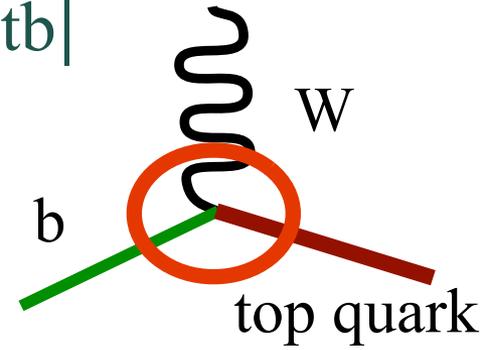
- Top mass measurement
 - predict Higgs mass
- CKM matrix element ratio
- tWb coupling - W helicity
- top-gluon coupling - total cross section measurement
- top quark charge
 - electromagnetic coupling



Single top production

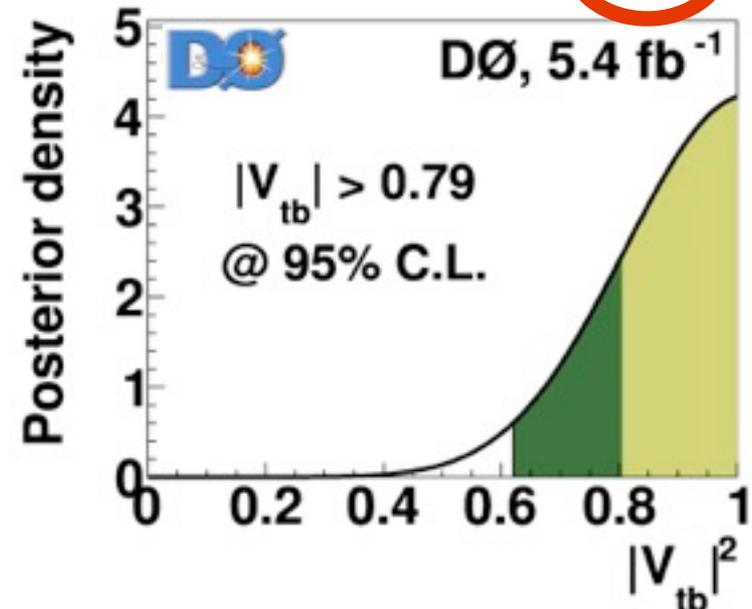
- tWb coupling - total cross section measurement
- measure CKM matrix element $|V_{tb}|$ directly
- tWb coupling - top quark spin
- b-quark content of proton

CKM matrix element $|V_{tb}|$

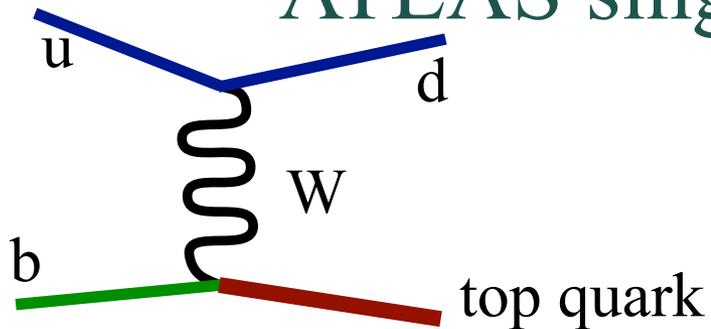


$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

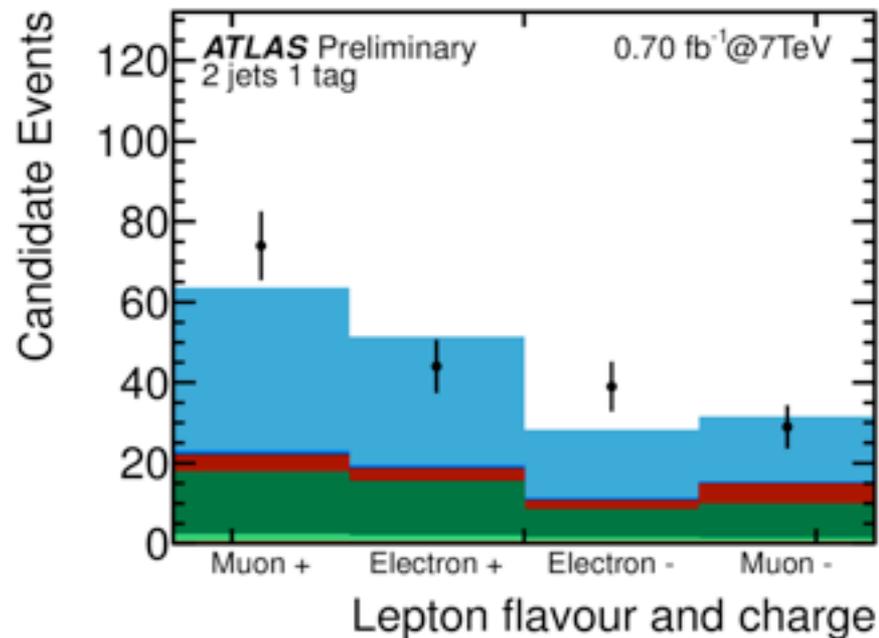
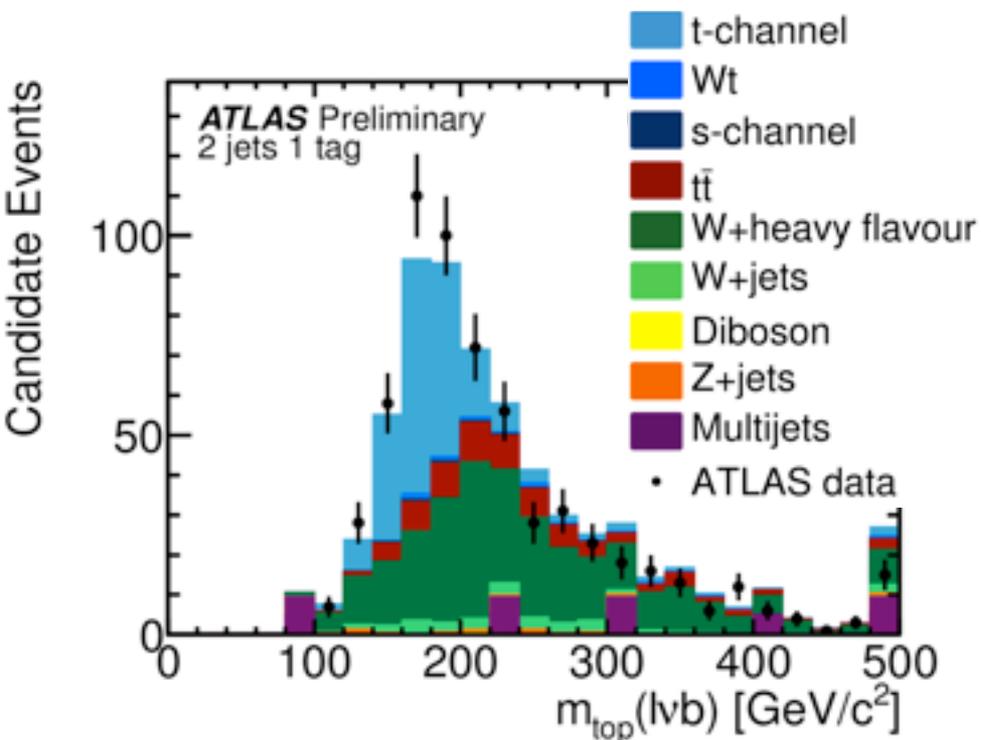
- Cabibbo-Kobayashi-Maskawa quark mixing matrix
- Single top cross section proportional to $|V_{tb}|^2$
- No assumptions about number of generations or unitarity of CKM matrix



ATLAS single top measurements



- Cut-based analysis and Neural network analysis



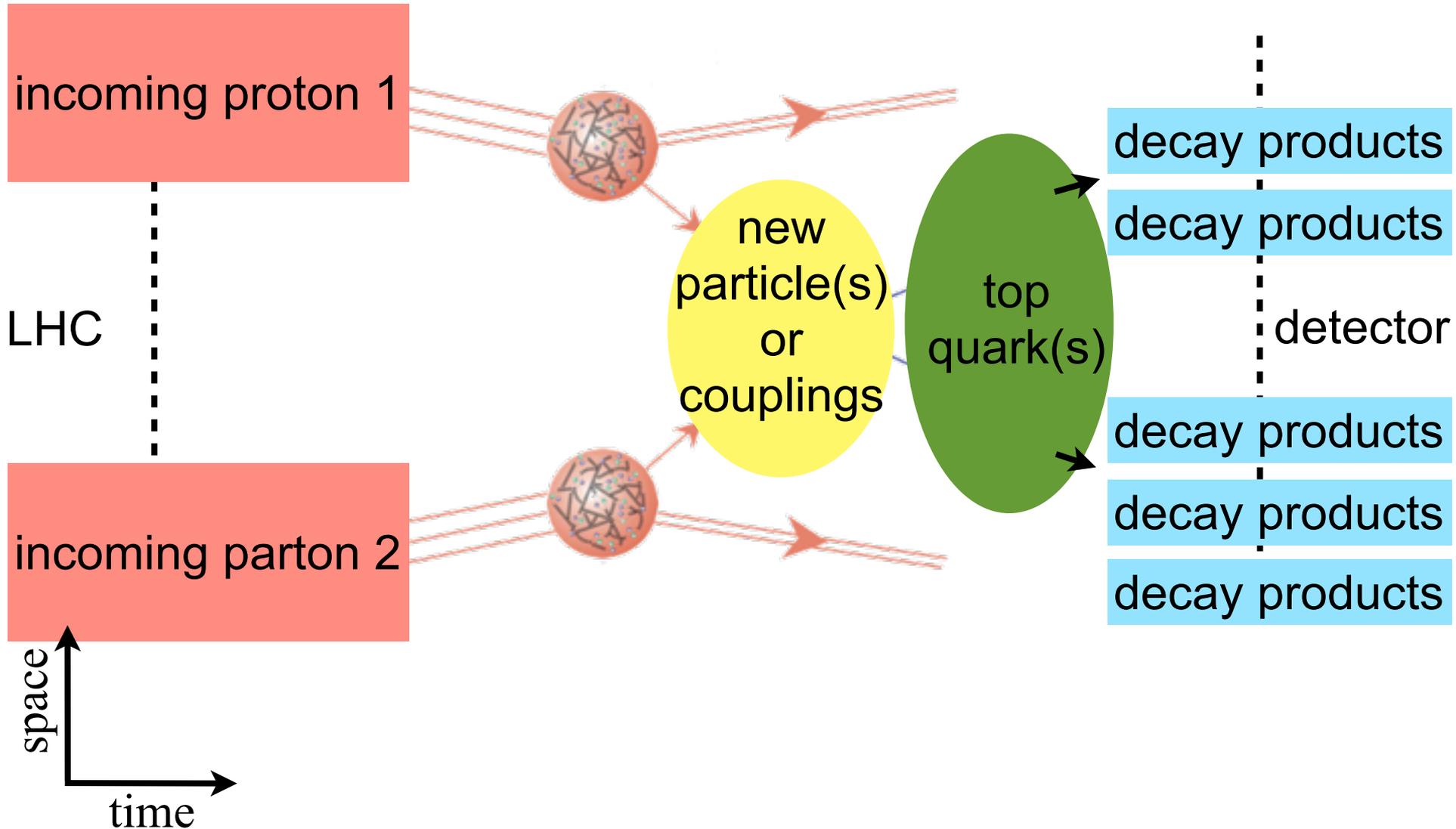
SM expectation: 65 pb

Observed cross section:

$$\sigma_t = 90^{+32}_{-22} \text{ pb}$$

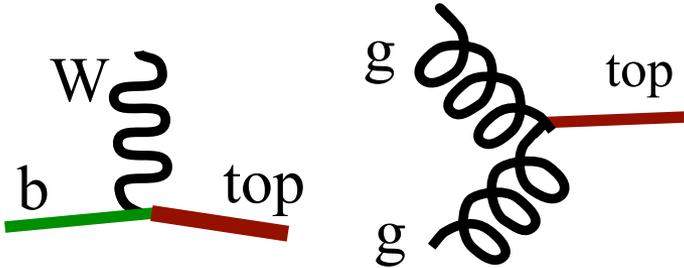
Searches for new physics

New physics production with tops



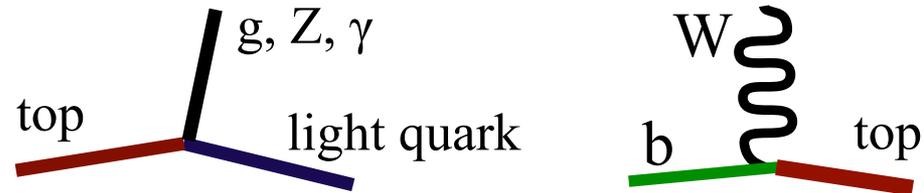
Top quark future

Precision Measurements

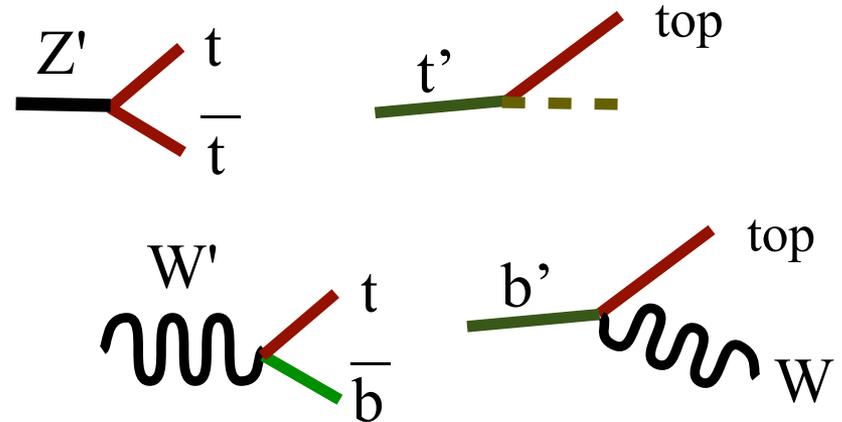


- couplings
- CKM matrix
- CP violation
- top spin
- top mass

Modified/new couplings



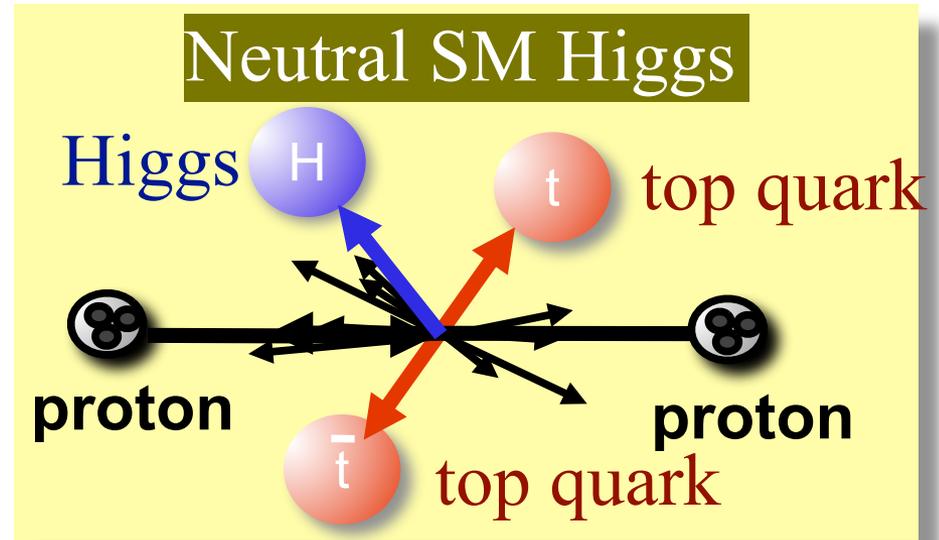
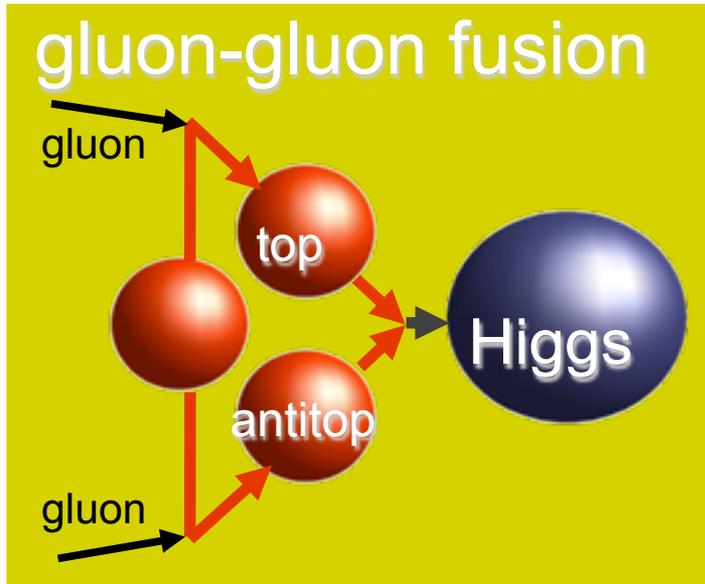
New particles



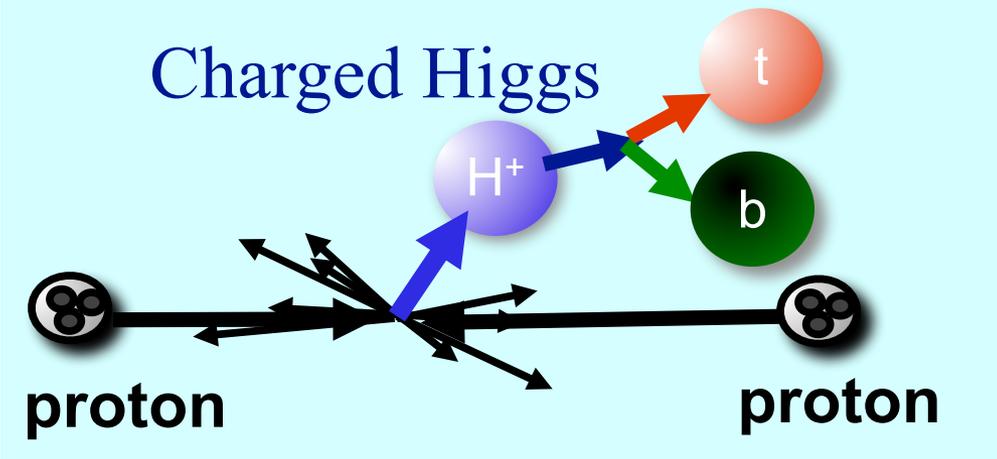
Coupling to new particles discovered first elsewhere



Higgs boson production at the LHC



Supersymmetry: Charged Higgs



Reaction from Peter Higgs



Summary/Outlook

- Higgs searches have resulted in discovery of a new boson
- Is it the Higgs we expect?
 - Measure couplings to bosons and fermions
 - Measure coupling to different quarks
- Is there other new physics?
- What is dark matter?
- Top quark measurements can provide important insight
 - Gateway to Higgs and other new physics

Backup slides

Single top observation party



Electroweak symmetry breaking - Why is the weak force so weak?

Gauge boson coupling to Higgs field

